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PROGRESS REPORT #4

INVESTIGATION OF THE EFFECTS OF EXTERNAL CURRENT SYSTEMS ON THE MAGSAT DATA UTILIZING GRID CELL MODELING TECHNIQUES

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16. Abstract

The overall objective of this effort in support of the Magsat project is to study the feasibility of modeling magnetic fields due to certain electrical currents flowing in the earth's ionosphere and magnetosphere. This fourth quarterly status and technical progress report discusses progress made in reading Magsat data tapes and in the modeling procedure that has been developed to compute the magnetic fields at satellite orbit due to current distributions in the ionosphere and magnetosphere. The modeling technique utilizes a linear current element representation of the large-scale space-current system.

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I. INTRODUCTION

The overall goal of this investigation is to study the feasibility of modeling the magnetic fields produced by certain electrical currents flowing in the earth's ionosphere-magnetosphere system. Vector magnetic field measurements from the near-polar orbiting Magsat satellite contain, in addition to the main geomagnetic field and crustal anomaly fields, contributions that arise from these external currents. In fulfilling the ultimate goals of the Magsat project, it is desirable that the external current effects be identified in the observations and subsequently separated from the internal field. The objective of this investigative effort will be to determine the capability of a modeling procedure to facilitate the separation of these external and internal components.

The approach of this feasibility study shall be to develop forward modeling procedures through which the magnetic effects of model currents may be derived. It is intended to include, separately, the equatorial electrojet, S_q currents, and the effects due to auroral zone and polar cap currents including the high latitude ionosphere-magnetosphere coupling currents. In each case candidate current systems will be devised and resulting "typical" magnetic field signatures calculated for comparison with Magsat observations.

II. ACCOMPLISHMENTS DURING REPORTING PERIOD

1. Data Reduction

In previous quarterly reports, we have discussed the development of soft-ware programs to read the Magsat Chronicle format data tapes on a U.T.D. PDP 11/45 computer, and to printout either the orbital data alone or both orbital and magnetic field-values from both scalar and vector magnetometers for a specified time period contained on the source tape.

The program computes geodetic longitude and latitude, and altitude of the spacecraft and outputs this information along with inertial and magnetic coordinate positions. The magnetic field measurements during each second are read and the maximum, minimum, and average values for each scalar head and each vector component are printed at one-second intervals.

During this fourth quarter the major emphasis of our investigation has been placed on Magsat data reduction programs. The software package described above has been extended so that selected portions of Magsat data can be stored on magnetic disc. Additional data reduction software has been developed that accesses the stored data, subtracts a spherical harmonic model field, and plots each of the three resultant magnetic component deviations and the scalar field difference on a high resolution interactive vector graphics terminal. This new software has given us the capability to visualize the measured magnetic field perturbations along the Magsat orbit. This will permit direct comparisons between the measured magnetic field perturbations which arise from external currents, and the model results described below.

2. Field Modeling

Previous quarterly reports have described a modeling technique that is being developed to compute the magnetic effects at Magsat altitudes due to hypothetical currents in and above the high latitude ionosphere. In this forward modeling technique prototype current systems representing the auroral electrojet and ionospheric polar cap currents as well as the field-aligned currents that link these low altitude currents to the distant magnetosphere are devised. This current system is then represented for computational purposes as an array of linear current elements having finite length and a finite diameter with a pre-determined cross-sectional current density distribution within each element. For each observation point along a hypothetical satellite orbit, the three vector components of the resultant magnetic field

are computed as a superposition of the field contributions due to each current element in the world-space. The resultant magnetic perturbations for each vector-field component are displayed on a high-resolution vector graphics terminal by means of a computer program designed to allow the operator to interactively modify the model parameters.

The initial stages of development of this model discussed in the first quarterly report had been restricted to satellite orbits at 90° inclination in the dawn-dusk meridian plane and the initial computations included only the sunward component of the perturbation field at various altitudes. During the second quarter the capabilities of the model were extended to allow the computation of three vector components of the magnetic field arising from a prototype current system. Furthermore, the restriction on satellite orbits was almost entirely eliminated allowing the magnetic field components to be computed for virtually any satellite orbit over a wide range of inclinations and altitudes and having an arbitrary orientation of the orbital plane with respect to the earth-sun line. During the third quarter of this contract, two major extensions of the magnetic field modeling software were made that significantly extended the ability of the model to handle realistic current systems and allow presentation of the results more realistically. The capability for ionospheric current closure in the east-west direction was added to the model. Furthermore, modifications were made to allow the resulting magnetic field perturbations to be computed and plotted in an N,E,V coordinate system.

Although the major emphasis during this quarter has been on Magsat data reduction, some effort has also gone into modeling. The model has now reached a level of delopment whereby extensive testing of its predictive capabilities can begin. Pursuant to that end, we have taken the initial steps to conduct comparative modeling of an agreed-upon input ionospheric and field-aligned current system in cooperation with the National Research Council of Canada group.

A second test of one portion of our new modeling package was carried out using a horizontal ionospheric current system published by Akasofu et al. (Journal of Geophysical Research 86, 3389, 1981). These researchers have deduced a model of the total ionospheric current distribution based upon 5 minute averages of the magnetic field measured on the ground with the Alaska Meridian Chain of Magnetometers. Using a likeness of their ionospheric current distribution from Figure 4 of the referenced pages), we have calculated the three-dimensional field-aligned current distribution around the polar ionosphere that would be required to maintain continuity of the total current system. Our results are shown in the figure accompanying this report. This figure is a color-coded representation of the direction and magnitude of the resulting field-aligned current densities over the polar region. The color hues of the red-orange-yellow portion of spectrum represent varying intensities of downward directed currents and those of green and blue represent various intensities of upward directed currents as shown in the bar scales in the lower right hand corner. The gross features of this plot closely resemble those deduced by Akasofu et al and shown in their Figure 5. This pattern is also generally consistent with the overall empirical distribution of Region 1 and Region 2 field-aligned currents deduced from satellite data. Our model has also been used to produce the magnetic field perturbations that would be observed from a satellite passing through this current system, as well as those that would be observed on the ground below. Those latter distributions should compare with the input magnetic field measurements used by Akasofu.

3. Other Activities

During this quarter the principal investigator traveled to Edinburgh, Scotland to participate in the Magsat Investigators meeting and to present a paper at the subsequent Fourth Scientific Assembly of the International Association of Geomagnetism and Aeronomy. That paper, entitled "A Tech-

nique for Modeling the Magnetic Perturbations Produced by Field-Aligned Current Systems", discussed some of the first results of our field modeling procedure. The major conclusions of this work were that:

1. Significant magnetic field perturbations due to auroral zone currents extend to latitudes well equatorward of those normally associated with the auroral zone, even when no currents flow at these low latitudes. The implication is that spherical harmonic models of the earth's main magnetic field may be subject to contamination from external current effects even when data is used only within +50° to -50° latitude.
2. For a balanced Birkeland current system in which all of the field-aligned current closes in the north-south direction between the Region 1 and Region 2 current sheets, the model predicts that these will still be a so-called "polar top-hat" in the east-west magnetic field perturbation over the polar cap. Hence the existence of a polar top-hat should not be interpreted to imply a net field-aligned current in the Region 1 system. Furthermore, such a top-hat perturbation does not require a cross polar cap current, as has been suggested by some researchers.

III. PROBLEMS ENCOUNTERED AND RECOMMENDATIONS

No major problems have been encountered.

IV. PLANS FOR NEXT REPORTING INTERVAL

Although the primary goal of this investigative effort is to develop field modeling techniques for the near-earth magnetic field arising from external currents, such development cannot be successfully be carried out without concomitant study and analysis of the actual Magsat Data. Hence during the forthcoming quarter the emphasis of our activity will be placed on further development of data reduction software. Additional on-line interactive capability for use with the computer routines to store and display selected

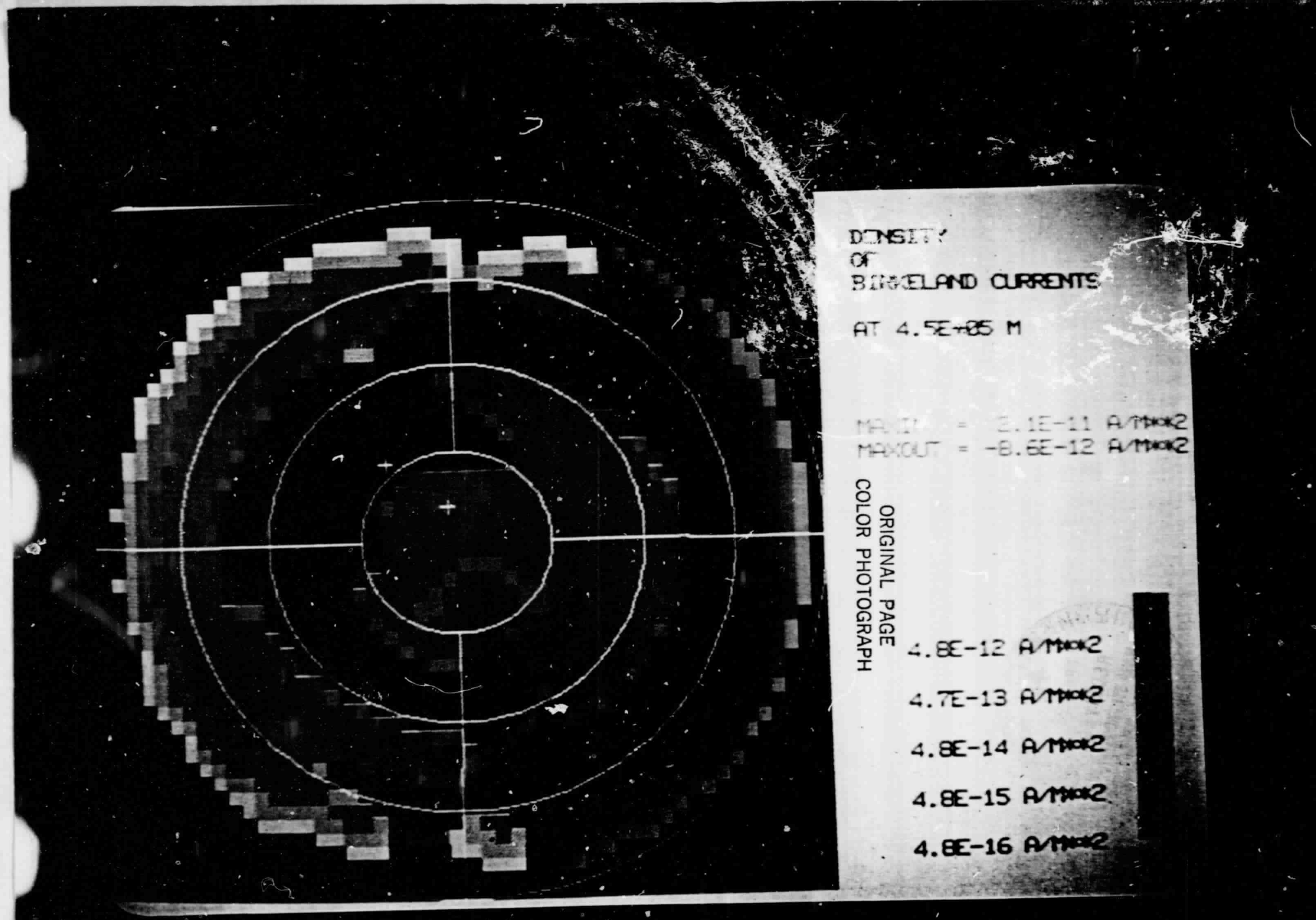
portions of Magsat data will be developed.

The linear element field modeling procedure will undergo extensive testing during the next reporting period. The emphasis will be placed upon utilizing the flexibility built into the software to choose diverse sets of initial current configurations. This built-in flexibility will allow us to further "prove out" the model by comparing the results of our predictive capability with those of the National Research Council of Canada group who are using a modified Kisabeth technique to compute the magnetic perturbations that arise from an assumed current distribution. Previous discussions with a representative of this group have resulted in agreement on an input current configuration and a set of locations for modeling the resulting field perturbations. We also expect to conduct more extensive comparative testing our our model with the Alaska group under the direction of S-I Akasofu who have also been using the Kisabeth technique to model the current distributions that produce magnetic perturbations in the observations from a meridian chain of magnetometers located in Alaska.

It is also planned that the modeling technique should ultimately include effects due to currents in the S_q current system and in the equatorial electrojet. These currents have not until now been included in the model. During the forthcoming quarter we will begin to develop a model of the magnetic field due to these currents that can be added to the polar current effects presently being analyzed.

V. FUNDS EXPENDED

The total expenditure of funds under this contract through the end of this reporting period (September 30, 1981) is estimated to be $32,700.00.


DENSITY
OF
BIRKELAND CURRENTS
AT 4.5E+05 M
MAXOUT = -8.6E-12 A/M**2
4.8E-12 A/M**2
4.7E-13 A/M**2
4.8E-14 A/M**2
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